MODELLING A HYBRID SYSTEM PV/WIND GRID CONNECTED WITH STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

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ABSTRACT

Whenever photo voltaic and wind power production are used together, the reliability of the power grid is enhanced. But this combined hybrid system needs controlling and Compensation, to overcome this problem, we use Static Synchronous Compensator (STATCOM) to stabilize the power supply at the grid side after many disturbances via Voltage Sag, load changes, Distortion etc. This thesis contain modelling of Photovoltaic renewable energy system to produces maximum 5 KW/h. Moreover, the study contains modelling of wind energy system to produces 1.5 KW/h. reducing the effect of the intermittent nature of renewable sources on the electricity generation is a challenging task. The maximum power is 6.5 KW/h obtained using hybrid system. This thesis investigates the use of a Static Synchronous Compensator (STATCOM) along with wind energy and solar for the purpose of stabilizing the grid voltage using MATLAB/Simulink.

ABSTRAK

Apabila foto voltan dan pengeluaran kuasa angin digunakan bersama-sama, kebolehpercayaan grid kuasa dipertingkatkan. Tetapi gabungan sistem hibrid ini memerlukan pengawalan dan Pampasan, untuk mengatasi masalah ini, kami menggunakan Static Synchronous Compensator (STATCOM) untuk menstabilkan bekalan kuasa di sebelah grid selepas banyak gangguan melalui Voltage Sag, perubahan beban, Distortion dll. Tesis ini mengandungi pemodelan Sistem tenaga boleh diperbaharui fotovoltaik menghasilkan maksimum 5 KW / h. Selain itu, kajian ini mengandungi pemodelan sistem tenaga angin untuk menghasilkan 1.5 KW / h. mengurangkan kesan sifat seketika sumber yang boleh diperbaharui pada penjanaan elektrik adalah tugas yang mencabar. Kuasa maksimum ialah 6.5 KW / h yang diperoleh menggunakan sistem hibrid. Tesis ini menyiasat penggunaan Static Synchronous Compensator (STATCOM) bersama-sama dengan tenaga angin dan solar untuk tujuan menstabilkan voltan grid menggunakan MATLAB / Simulink.

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LIST OF SYMBOLS AND ABBREVIATIONS

PV	-	Photovoltaic
HRES	-	Hybrid Renewable Energy Systems
HAWT	-	horizontal axis wind turbines
VAWT	-	vertical axis wind turbines
FACTS	-	Flexible Alternating Current Transmission System
CSP	-	Concentrated Solar Power
SSSC	-	Static Synchronous Series Compensator
TCSC	-	Thyristor controlled series capacitor
SVC	-	Static Var Compensator
STATCOM	-	The Static Synchronous Compensator
UPFC	-	Unified Power Flow Controller
IPFC	-	Interline Power Flow Controller
DG	-	Distributed Generation
RES	-	Renewable Energy Systems
MW	-	megawatt
DC	-	direct current
AC	-	alternating current
PMSG	-	permanent magnet synchronous generator

CHAPTER 1

INTRODUCTION

1.1 Background

It is now a globally accepted reality that electrical energy is fundamental for social and economic development. Unfortunately still one third of the world's population lives in developing and threshold countries and have no access to electricity [1]. It has been estimated that the world population will reach 8 billion by 2020. The statistic shows that the population growth is mostly in developing countries where most of the people live in remote, rural areas. The extension of utility grid is complicated and expensive due to geographical, economic and social barriers. Up to now, mostly diesel genets are used for rural electrification. This is not a good solution because the fuel and maintenance cost are expensive and it is also not environment friendly. In such circumstances, an alternative is to use locally available renewable energy sources (e.g. PV, wind, hydro etc.) and implement modular, expandable and task-oriented system concepts that guarantee cost-effective and sustainable resources of energy, especially for remote and rural areas [2]. At the world engineering convention in 2000, it has been mentioned that the energy needed will be provided, distributed , and consumed in a suitable way.

Keeping this promise in mind, many decentralized HPS have been installed worldwide. A photovoltaic (PV) system coverts light energy into electricity and the basic device of PV System is a Photo voltaic cell. These PV cells may be combined or grouped to form PV arrays or PV panels. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and dc motors[2]. Photovoltaic cells are made of several types of semiconductors using different manufacturing processes the goal of this current research is to examine “The Modelling hybrid PV/wind grid connected using STATCOM device” Renewable energy sources are not destroyed when their energy is exploited. The use of renewable energy sources requires technologies that exploit natural phenomena, such as sunlight, wind, waves, water flow, and biological processes such as anaerobic digestion, biological hydrogen production and geothermal heat. Among the above mentioned sources of energy, wind has played a vital role in the exploiting of energy. The motion of air masses produced by the irregular heating of the earth’s surface by sun is called wind. Wind energy varies continuously and provides energy in sudden fragments and is not a constant source of energy [3]. In this paper, Permanent Magnet Synchronous Generator is being used because of having better performance due to higher efficiency. STATCOM is a regulating device used in the alternating current transmission networks. It is based on a power electronics voltage-source converter and can act as either a source or sink of reactive AC power to an electricity network. It can also provide active AC power if we connect it to a source of power. It also supports if there is poor power factor and often poor voltage regulation [4]. STATCOM has many advantages which includes wind energy voltage stabilization, and harmonic filtering. In this paper, Hybrid solar, wind generating system is modelled with STATCOM to stabilize grid power supply which is being simulated in the MATLAB/Simulink Software. Human activities, the most important of which are the burning of fossil fuels such as coal, oil and gas, cause severe damage to the environment [5]. Climate change has become a significant problem for the young and the big and one of the most important problems affecting the national growth of any country [6]. The consumption of fossil fuels has doubled in recent years due to the increase in population across the globe. The fluctuation of oil prices caused economic disasters both for producing and importing countries.

The world has to turn to clean, renewable and environmentally friendly alternatives such as solar, wind and geothermal energy [7]. Solar energy has gone a long way and solar power plants are now available in most parts of the world. They can also be generated at the house level and are connected to the network or unrelated [8]. The use of wind energy in electrical systems has been increased in all over the world in the recent years. Many new problems have appeared which developed a demand for treating these problems related to making the electrical system stable. This system naturally has variable energy resources as steam plants, gas, atomic, hydraulic , and photovoltaic and wind energy. The incidence of light on the cell generates charge carriers that originate an electric current if the cell is short circuited. Depending upon the light intensity, the Photovoltaic Array produces direct current . With the help of inverter or universal bridge, the dc power is being converted into ac power having phase and frequency [9].

1.2 Problem Statement

Renewable energy resources such as solar photovoltaic, wind are largely integrated into in power system. High penetration of RES causes issues in stability, voltage regulation and power quality of the system. The rapidly increasing costs of power line extensions and fossil fuel, combined with the desire to reduce carbon dioxide emissions pushed the development of hybrid power system suited for remote locations [10]. Hybrid power systems are designed for the generation and use of electrical power. Grid connected wind turbines are considered as better performers in recent times. But they give rise to lot of problems with respect to power transferred to grid, and reactive power control. Also when fault takes place in such a system, question of frequency range and power frequency characteristics, frequency control, reactive range capability and voltage control arises. During the normal operation, wind turbine produces a continuous variable output power, and these power variations are mainly caused by the effect of turbulence, wind shear and tower-shadow and of control system in the power system have been presented .Large disturbances such as a three-phase fault decelerate loads and cause instability to generating units. Further still continuous demand in electric power system network as well as heavy loading leading to system instability and straining of the thermal limits [11].

1.3 Objective

Objectives of this project:

I. To develop a photovoltaic system to produce 5 kW/h.
II. To develop a wind energy system to produce 1.5 kW/h.
III. To implement the grid connected PV/wind hybrid system with STATCOM and module in Simulink /MATLAB.
IV. To simulate and analyse of power system with and without STATCOM.

1.4 Scope of the Project

I. The project is about modelling and implementing Photovoltaic system to Product maximum 5 KW by using sw-280 PV cell due to its high stability Power.
II. Modelling and simulation of wind system renewable energy base permanent magnet synchronous generator (PMSG) generator to produce maximum power 1.5 KW.
III. The maximum power is 6.5 KW/h obtained using hybrid system.

IV. Modelling and implementing Static Synchronous Compensator (STATCOM) 100 KV by using matlab/Simulink.

V. The simulation of this power system is carried out by using MATLAB/Simulink software under windows operating systems.

1.5 Report outline

This report consists of 5 chapters namely, Introduction, literature review, methodology, Initial results and analysis and conclusion.

Chapter 1 this chapter would be covering the main concept of the research topic in depth of the research, research background opinion and the importance of the topic. Apart, this chapter covers the clear expatiation on the research aim research questions, research objective and the structure of proposed research.

Chapter 2, will show the detailed discussion of literature review. A comparison of voltage stability enhancement is performed for various FACTS devices on a five bus system.

Chapter 3 addresses of the research methodology which cover research design, data collection, sampling technique used by the data analysis method.

Chapter 4 discussion through the analysis and finally Chapter 5 will be summarizing the conclusion and followed by recommendation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This in this chapter literature related to photovoltaic cells, wind turbine, FACTS, STATCOM and the grid associated power quality issues and how to mitigate them.

2.2 Previous research

To delivers power to the rural areas in Ethiopia, a viability test led by [12] was conducted for an individual solar/wind based hybrid energy process. This work discussed the recreation of PV/wind/diesel and battery to provide power and voltage request for 200 families. The paper presented the most expense proficient mixture which is crossbreeding of diesel generator/battery and converter having no involvement of sources segments which are renewable. Other price operative mixtures of diesel generator/PV and converter were also offered by them, in this case the policy and tactic practiced was the load ensuing approach. The decision of the author is feasible to organize the above specified electric energy arrangements in the zones specified assets.

A research work conducted by [13] to estimate possibilities for off-grid electric transmission process in the rural areas in Bhutan. The examination was conducted in four areas in country. The foremost goal of this study was to enhance mixture power producing elements. PV/battery power producing system was considered to be inexpensive equipment for Gasa and Lunana.The operation of wind/battery system was enhanced for applying it in Yangtse site. The study was led [14] to enhance a wind turbine to present power plant of diesel schemes to diminish petroleum ingesting. The practicability of the systems (hybrid) guaranteed at wind velocity of 5.48m/s, lowest renewable portion 0% and $0.162/litter petroleum price. Kasukana, et al [15] examined the practicability of hybrid renewable electric systems as primary energy necessity for portable telephone places in Congo. In three different places, the study were conducted and not linked to the grid such as like; Mbuji-Mayi, Kabinda and Kamina. The prospective arrangement of different styles as shown in many studies are; diesel generator, PV-wind turbine and pure PV arrangements were configured.

Elhassan, et al [16] defines the strategy and application of well-organized energy (renewable) motorized system for domestic usages in Khartoum in Sudan. The reproduction action was been achieved for the distinct families and Roundabout for almost 10 to 15 families. To finalize several prices, distinct home CODE is about 49.5 SP/Wh, for 10 households.

Hossain [17] presented a paper on modelling a wind-solar hybrid system for rural applications. The model was developed to simulate a stand-alone power system with battery storage. The model was applied to a typical consumer peak load of 1 kW at a remote community in Bangladesh . An economic analysis was also undertaken to assess the feasibility of such a system at the location considered.

Chang [18] discussed the modelling and application of a wind-solar energy hybrid power generation system based on “multi-agent” technology. Through the collaboration of multi-agents, the control system of the wind-solar topology was optimised and its intelligence and reliability were enhanced.

Castle [19]published a paper about analysing the merits of a hybrid wind-solar concept for Stand-alone systems. The methods for evaluating the benefits of such systems for stand-alone Applications were developed. It was discovered that the optimum mix of wind and PV power with an electrochemical storage system, with or without fossil fuel generator backup, depends upon the individual subsystem economics. A computer code was developed to calculate the optimum subsystem-sizes that could minimise the energy cost. It was found that the actual merits of a hybrid system over a pure PV or wind system depend upon many factors including load Profile, wind regime, insulation, cost and availability of backup power, and so on.

CADDET Centre for Renewable Energy [20] gave a project on a wind-solar hybrid system in Bullerö Island, Sweden. This report gave ideas about how the wind-solar power installation can meet almost all the island's energy demand with less than half the cost of installing grid connection. Thus, they proved that this method was a cost-effective use of renewable energy in remote places.

2.3 Solar Energy

A Solar power is usable energy generated from the sun in the form of electric or thermal energy. Solar energy is captured in a variety of ways , the most common of which is with photovoltaic solar panels that convert the sun's rays into usable electricity. Aside from using photovoltaic to generate electricity, solar energy is commonly used in thermal applications to heat indoor spaces or fluids. Residential and commercial property owners can install solar hot water systems and design their buildings with passive solar heating in mind to fully take advantage of the sun's energy with solar technology[21]. Solar panels are installed at three main scales: residential, commercial , and utility . Residential-scale solar is typically installed on rooftops of homes or in open land (ground-mounted) and is generally between 5 and 20 kilowatts (kW), depending on the size of a property . Commercial solar energy projects are generally installed at a greater scale than residential solar. Though individual installations can vary greatly in size, commercial-scale solar serves a consistent purpose: to provide on-site solar power to businesses and non-profits. Finally, utility-scale solar projects are typically large, several megawatt (MW) installations that provide solar energy to a large number of utility customers[22].

2.4 Review on PV technology

A PV technology has been viewed as a promising solution for the ever growing energy crises since the past few decades. The fact that prices KWh produced per cell are dropping. Furthermore the technological advancement in regards to other components of the system, more efficient inverters and less expensive batteries[9].

The principle of photovoltaic when light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current. An array of solar cells converts solar energy into a usable amount of direct current (DC) electricity. An inverter can convert the power to alternating current (AC)[23].

2.4.1 Types of PV cells

Based on the technology and techniques used to manufacture the PV cell, the most commonly used commercial cells are of one of the following type, Mono-crystalline, Poly-crystalline and thin film. Each has its own applications depending on the efficiency and the space available. Table 2.1 illustrates the different types of PV cells and their respective efficiency levels.

I. Mono-crystalline Silicon PV: To produce mono-crystalline silicon a crystal of silicon is grown from highly pure molten silicon. This single crystal cylindrical ingot is cut into thin slices between 0.2 and 0.3mm thick- this is the basis of a solar PV cell. The edges are cut off to give a hexagonal shape so more can be fitted onto the module. These PV cells have efficiencies of 13-16% and are the most efficient type of the three types of silicon PV cell. However, they require more time and energy to produce than polycrystalline silicon PV cells, and are therefore slightly more expensive [24].

II. Polycrystalline Silicon PV: Polycrystalline silicon is also produced from a molten and highly pure molten silicon , but using a casting process. The silicon is heated to a high temperature and cooled under controlled conditions as a mauled. It sets as an irregular poly- or multi-crystal form. The square silicon block is then cut into 0.3mm slices. The typical blue appearance is due to the application of an anti-reflective layer. The thickness of this layer determines the colour- blue has the best optical qualities. It reflects the least and absorbs the most light. More chemical processes and fixing of the conducting grid and electrical contacts complete the process. Mass-produced polycrystalline PV cell modules have an efficiency of 12-16% [24].

III. Thin film P-V cell Cells made from this material are found in pocket calculators etc. The layer of semi-conductor material is only 0.5-2.0um thick, where 1um is 0.001mm. This means that considerably fewer raw materials are necessary in their production compared with crystalline silicon PV production. The film of amorphous silicon is deposited as a gas on a surface such as glass. Further chemical processes, the fixing of a conducting grid and electrical contacts follow. These PV cells have an efficiency of between 6-8%. Multi-junction amorphous thin film PV cells with each layer sensitive to different wavelengths of the light spectrum are also available. These have slightly higher efficiencies. This type of PV cell is not currently suitable for use on residential developments due to the low generation density[25]. Table 2.1 shows the different panel types and their respected parameters [25].

Figure 2.1: PV cells types (a) Mono crystalline, (b) Poly-crystalline and (c) Thin film

Table 2.1: Solar modules types and efficiencies

Type of solar panel	Production scale	Max efficiency (%)	Max output Power (W)	Cost (US/W)
Mono-crystalline	Large scale	25%	320	0.7
Poly-crystalline	Large scale	20.4%	320	0.7
Thin film	Small	12.2	300	0.8

2.4.2 Basic Components of a Solar PV System

Solar PV system includes different components that should be selected according to your system type, site location and applications. The major components for solar PV system:

I. Solar panels (PV or PV modules) convert daylight to electricity. A number of modules are connected together to increase the electrical power that can be generated. The entire bank of modules may be referred to as the solar array.

II. DC Isolator provides a safe means of disconnecting the solar array from the inverter, for example for periodic maintenance. Some inverters have integrated DC isolators.

III. Inverter converts the Direct Current (DC) electricity produced by the solar panels to the Alternating Current (AC) form that is required for the National Grid and for the operation of most electrical appliances need. Also, the inverter provides a fail-safe link between the solar generator and the mains electricity network. If there were a problem with the PV system or (more usually) a fault on the electricity network, the inverter would make the system safe.

IV. Generation meter accurately counts the numberv of units of electricity created by the PV system. This is important for the measurement of the feed in tariff revenue.

V. AC isolator is included to provide a means of disconnecting the solar PV system from the building electricity supply. This may be important if there is an emergency, but (more usually) is needed when electricians have to do work on the building supply.

VI. Consumer Unit (Fuse board) the main point of connection of the PV system into the building supply.

VII. Existing supply meter when you need more electricity than your solar PV system is generating (for example during the night), you will draw power from the mains supply. Any electricity that you draw from the grid will be registered on your supply meter as normal. If our installer has installed an import / export meter, then this will also register the amount of excess production that is fed back into the grid.

VIII. The Grid, the main electricity network which supplies power to you may now also supply excess solar PV production to other consumers.

2.4.3 Connection of PV system

The PV system can be classified on the basis of its connection method. There are two basic classification in this criteria, Off-grid and Grid-connected systems.

2.4.3.1 Off-Grid (standalone) system

Also known as battery backup systems it is possible to install a solar system that is independent of the electrical grid. This is called an off grid system, and it requires that the solar panels are able to produce enough electricity to cover 100% of the energy needs of the building. Most homes have higher electricity demand in the evening or at night, so off grid systems usually incorporate either a battery (to store energy produced during the day), a backup source of energy (like a generator), or both. Off grid systems are more complex and less flexible than grid tied systems. Off grid systems are most common in remote locations without utility service. Off grid solar electric systems operate independently from the local utility grid to provide electricity to a home, building, boat, (or remote agricultural pumps, gates, traffic signs, etc.). These systems typically require either a battery bank (to store solar electricity for use during night time or cloudy weather) a backup source of energy (like a generator), or both. An off grid solar system must be large enough to produce enough electricity to cover 100% of the energy needs of the building. In all off grid scenarios, electrical usage must be monitored and kept below the maximum output of the panels and batteries as there is no grid source to supply excess power. System components consists of: PV panels, battery bank, charge controller (to protect the battery bank from overcharge), inverter to convert the stored energy in battery to power up the AC loads in the required electrical safety gear (i.e. fuses, breakers, disconnects) monitoring system to balance energy consumption with production[26].

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